



Calculation Book Report

Date: November 8, 2017

Technical Owner: Civil – Brett I. Kesterson, P.E.

Calculation Book No. 440 **Standard Drawing No.** P-440

Drawing Title: 14' Asphalt Local Speed Bump



Expires 06/30/2019

The first version (1991) was 12' long instead of 14' and based on a Florida 22' speed table without the flat 10' table portion. In the initial testing, the 85th percentile speeds were reduced below the 25 mph posted speed limit. The City of Portland Attorney advised that such an effect was likely not defensible in court. The solution to increase the 85th percentile speed to just above 25 mph was to increase the length of the bump to 14'. The 3-inch height was chosen based on a survey of what other jurisdictions were doing at the time. Since then, it is now the recommended height by the Institute of Transportation Engineers.

The Mulder file outlines the beginning history of the speed bump program along with testing of speed bumps.



Mulder-Kathy-1998.
pdf

The PDX file outlines the analysis made to make sure speed bumps would not adversely impact emergency vehicle response time, especially large fire apparatuses.



PDX_StudyTrafficCal
mingDevices.pdf

The Brief History file outlines the history of the traffic calming program in Portland from the 1980's to 2013.



A Brief History of
Traffic Calming in Pc

Calculations made by:
Name: Brett I. Kesterson, P.E.
Title: Senior Engineer

Report Date November 8, 2017:
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P-440 Calculation Report

While the speed bump design is fairly straight forward, it is important to carefully design the placement of the speed bumps so as not to create other problems. The two pdf reports above give a good lessons learned for the City of Portland. Other things to consider in any installation are:

- Do not put speed bumps on streets which are in very poor condition
- Be prepared to take out speed bumps if they become an issue for transit agency
- Be flexible to revise plan where speed bumps are placed in response to road geometry

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- Be prepared to take out speed bumps if they become an issue for transit agency
- Be flexible to revise plan where speed bumps are placed in response to road geometry

Split Speed Bump

Kathy Mulder, PE, City of Portland, Oregon, Traffic Calming Program*

January, 1998

Introduction

History/Problem

Test and Test Plan

Conclusions and Recommendations

Introduction

Speed bumps have been found to be very effective at slowing traffic on residential streets throughout the City of Portland. City residents have embraced these devices as a means to slow traffic and enhance their livability.

The speed bump programs began in 1992 after several months of test and evaluation with two bump designs. The 14 foot speed bumps, only used on Local Service Streets (the lowest classification of streets in the City), slow passenger cars and light vans so that the 85th percentile speed along the street is between 24 and 28 mph. The 22 foot speed bumps allow an 85th percentile speed of 29 to 34 mph.

The Fire Bureau expressed concern that the 22' speed bumps are slowing their trucks and engines causing a negative impact on the Fire Bureau's 4 minute "fire response time" goal. In a series of several speed bumps on primary fire response routes, valuable time is lost, endangering public safety. We needed to develop a solution that would address both aspects of public safety, rapid response by Emergency Services and traffic calming for residential streets.

History/Problem

In 1991 the City of Portland Bureau of Traffic Management undertook a study of speed bumps (humps) in response to public demands for some respite from the excessive and continual increase of traffic speeds. As the result of two years of testing, speed bumps became a standard 'tool' for addressing the problem of speeding on Portland's residential streets. In Phase III of the original 1992 speed bump tests, the " Fire Bureau indicated a maximum comfortable speed of 20 mph for the 14'...speed bump and 25 mph for the 22'...speed bump".

The 14' speed bump was adopted for local service streets that do not have transit or are not a primary fire response route. The 22' speed bump is designed for streets with high volumes of traffic, and those that are transit or primary fire response routes.

The Traffic Calming Program has been installing speed bumps since 1992, and in the fiscal year 1995-96, installed more than 100 new speed bumps. With so many bumps installed, and hundred's of streets on waiting lists, the Fire Bureau and the Bureau of Traffic Management became concerned about a "cumulative effect", or how several speed bump streets along any emergency route may impact the response time.

The goal of the Portland Bureau of Fire and Emergency Services is a response time of 4 minutes or less on 90% of emergency calls. A study was undertaken to quantify the effects of speed bumps on emergency vehicles. Measurements found that the amount of the time increase was dependent upon the type of vehicle and the type of traffic calming. Rescue vehicles were not slowed at all over the 22' bumps, while trucks and engines were slowed as much as 9 seconds per bump.

It was decided that an "emergency response route" street classifications would need to be developed, similar to the City's existing traffic street classifications², before any more traffic slowing devices could be placed on emergency response routes. This process of developing an emergency response route street classification and policies is a long and detailed task that can take several years to complete. All projects planned for streets currently used as primary routes by the Fire Bureau were put on hold until the classification process was completed.

In the meantime, excessive vehicle speeds continue to threaten public safety and neighborhood livability, and a great number of speeding problems are found on streets that also serve as primary response routes. The Traffic Calming Program needed a device that would both accommodate the Fire Bureau vehicles, and still slow speeding motorists.

Test and Test Plan

Since fire and emergency vehicles are allowed, by law, to use any portion of the street they need when on an emergency response run, we began with the concept of a chicane using two halves of a 22' speed bump separated by enough distance so that the emergency vehicle with the least amount of maneuverability could go through the chicane at approximately 20 mph.

Phase I

A Traffic Calming engineer and a Fire Bureau battalion chief used cones to build a simulation of the test device at the Fire Bureau Training Center. The vehicle selected by the Fire Bureau for testing was the vehicle with the least amount of maneuverability. The truck was 39 feet long, 8 feet, 4 inches wide, with a wheelbase of 18 feet, 6 inches. The street width used was 40'.

RESULTS OF PHASE I

In August of 1996, trial runs were conducted in the Fire Bureau Training Center lot, in a wide area of asphalt. A street segment and speed bump halves were outlined with cones, and runs were made through the split bump halves. After several runs, it was decided that the distance between the two lane bump halves needed to be at least 28 feet for the vehicle to maneuver through at or near 20 mph. Preliminary drawings of the new device were made and a field test was planned.

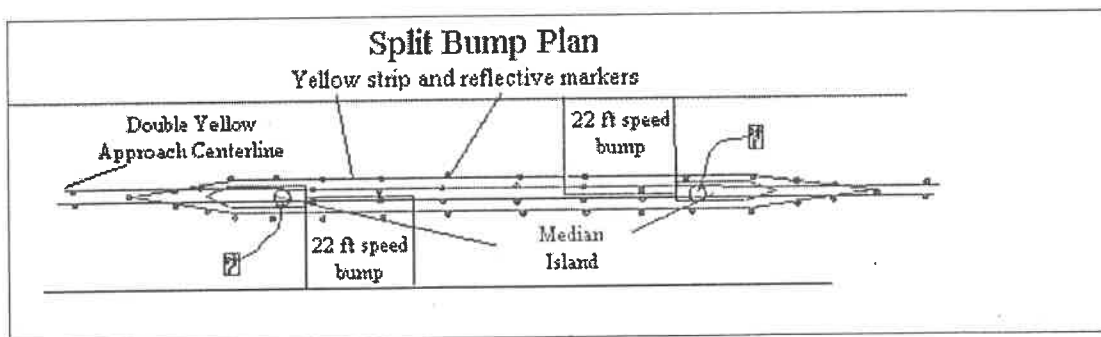
Phase II

Part 1 An actual street test location was selected that was part of an existing traffic calming project: SE Market Street between SE 117th and SE 112th Avenues. This street is 42 feet wide, has no horizontal curves, and the visibility along the street is excellent. This segment of SE Market is defined by a signal at SE 112th and an all-way stop at SE 117th.

Photos

The nearby fire station was notified and asked to make a few practice runs through the off-set speed bump and offer any suggestions they felt were appropriate.

The device was placed approximately 200 feet west of the all-way stop. The first part of the testing was for safety. Concerns of whether automobile drivers would violate the device and chicane between the bumps were raised. Twenty-four hour time lapse video equipment was placed to record driving patterns over the bump.



Part 2 This part of the initial testing was to determine if, and how fast fire vehicles were able to drive around the two bump halves. The largest Fire Bureau vehicles from the nearby station was used for the short test.

Part 3 The final part of Phase II was to place another split speed bump device approximately 600 feet west of the original device to determine the effect on speeds the two devices have in combination.

Total slowing effect on fire vehicles was tested. This was a controlled test that matched the original test that determined the time lost by speed bumps on fire vehicle response times.

RESULTS OF PHASE II

The 24 hour time-lapse video showed that drivers did not swerve into the oncoming lane to avoid the speed bump half in their lane. The temporary concrete medians and signs placed in advance of each bump half seemed to keep drivers in their own lane and over the speed bump. Dense centerline striping and raised reflective pavement markings gave an illusion that a median continued the entire distance between the bump halves. Subsequent 24 hour time-lapse video showed no indication of confusion on the part of the drivers, nor any violations of drivers trying to avoid the device at any time.

The results of the Fire Bureau vehicle testing were favorable. The vehicles were able to travel through the "chicane" at 17 to 21 mph. They indicated that the speed was quite satisfactory, and that this maneuver is no different than weaving around cars.

Concern was raised that a car may stop in the middle of the gap between bumps while the emergency vehicle approaches. There was fear that this device might prevent drivers from pulling off to the right when the emergency vehicles are running. Parking removal would alleviate this problem by providing an available refuge for cars pulling off to the right. If a car does stop in the middle of the device and blocks the fire vehicle pathway, the Fire Bureau decided that they would just go over the 22' bump. An occasional 22' speed bump does not create serious delay problems for them.

It was determined that parking removal would be necessary for the Fire Bureau to perform the chicane maneuver. Parking was removed on both sides of Market Street opposite each bump half.

Since it was found that the general public is willing to stay to the right of the centerline, two adjustments were considered to the companion device to be installed approximately 600' from the first device.

- The first adjustment was to make the approach islands shorter. It appeared that the "Keep Right" sign was enough to win driver compliance, and that the 20' island could be made smaller, just enough to place the sign.
- The second adjustment was to widen the gap between the two bump halves. This was done to explore how far apart the two bump halves can be and still maintain driver compliance on a straight stretch of street.

With the second device in place (installed 4/11/97) the street was measured for overall slowing effect. The effect on the 85th percentile speed was impressive. While control locations along Market Street (106th, 110th, 122nd) had no change in their 85th percentile speeds, the 85th percentile speed at the location between the two off-set bumps (114th) dropped from 37 mph to 26 mph.

85th Percentile Speed Changes on SE Market Street

Market St. Location	85th %ile Before Test (mph)	85th %ile with One Split Bump in Place	85th %ile with Two Split Bumps in Place
East of 106th Ave	40	36	37
West of 114th Ave*	37	35	26
West of 122nd Ave	34	33	34

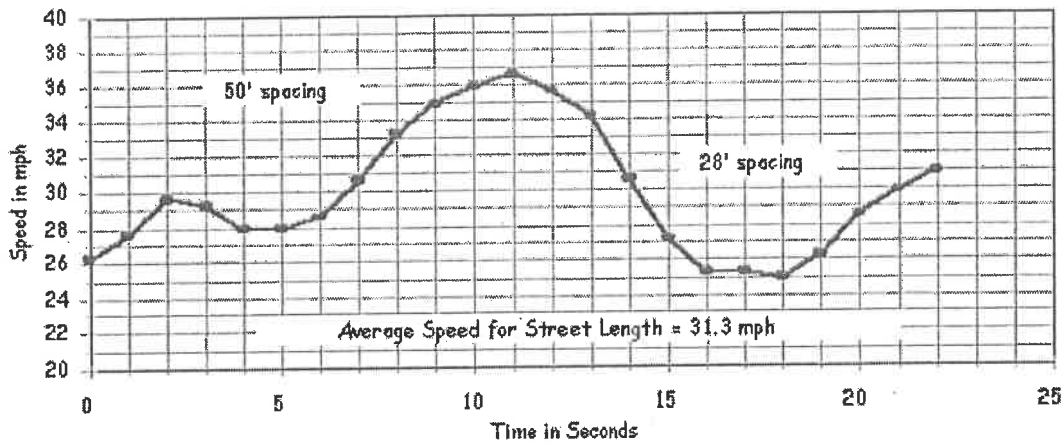
Table 1 * Between the two bump locations

Emergency vehicles ran timed tests through both of the new split bumps to determine the time lost by each vehicle. A truck and an engine were supplied for the test. These are the vehicles that had the greatest delay per device during the original testing of the other traffic calming devices.

Both vehicles were able to travel the length of the street at speeds between 29 and 31 mph. The vehicle speeds through the 50 foot off-set spacing were 26 mph to 30 mph. Between the 28 foot off-set spacing, speeds were 20 mph to 26 mph. It was found that the actual time lost was no more than 1 to 2 seconds for the largest of the vehicles.

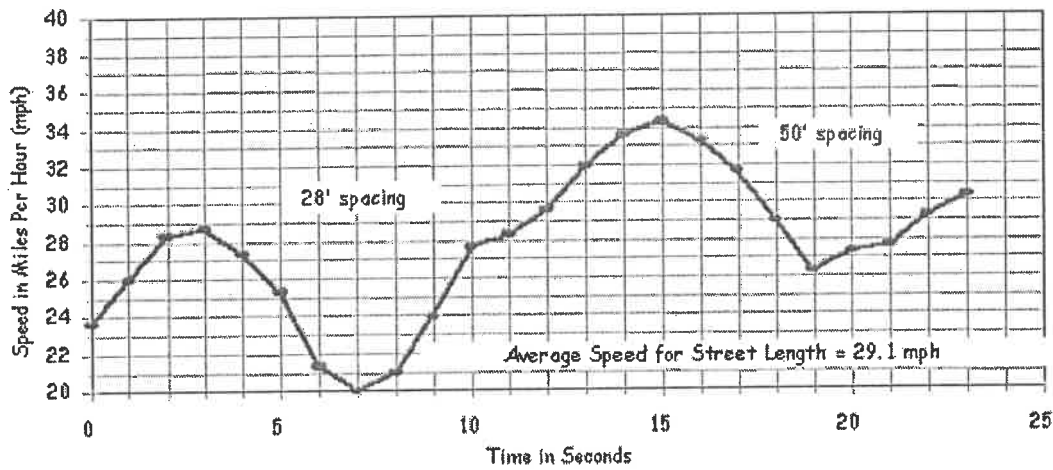
SE Market Speed Bump Test

Engine 41 Eastbound - Average



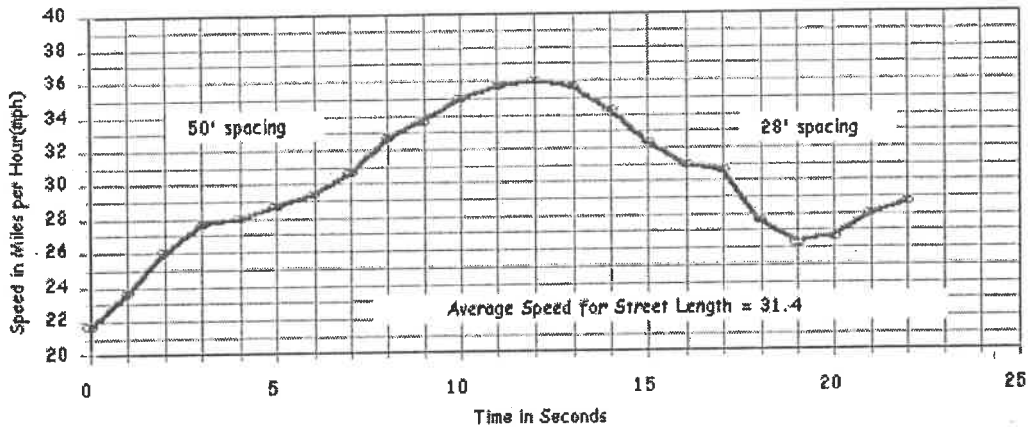
SE Market Speed Bump Test

Engine 41 Westbound - Average



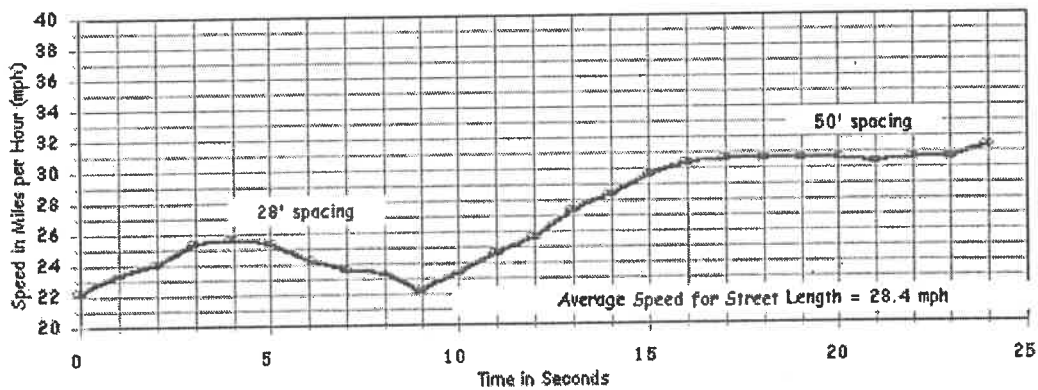
SE Market Speed Bump Test

Truck 41 Eastbound - Average



SE Market Speed Bump Test

Truck 41 Westbound - Average



The Fire Bureau is satisfied with the results and have no objections to limited use of this device. They asked that the distance between bump halves be greater than the original 28 feet. 50 feet was set as the standard minimum distance between the bumps. The distance may be extended, however, driver compliance must be maintained. It is hoped that the bump halves will be able to function as individual devices.

In reviewing the data for the test, it was noted that the slowest speeds, and therefore the most time lost, were at the off-set speed bump with the 28' spacing. The speed for the off-set speed bump with the 50' spacing never went below 25 mph.

Since the Fire Bureau believes that 25 mph is a reasonable speed for their vehicles on a Local Service street, it was concluded that the split bump, as it was designed with the 50' spacing, would meet their needs.

Based on the results of Phase I and II of the Off-Set Speed Bump Test, a third phase was initiated to determine some of the limitations of this new device.

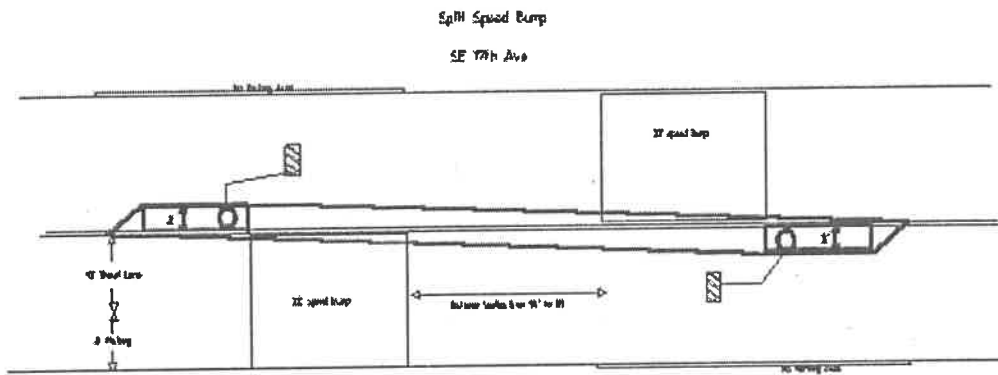
Phase III

The third phase of the testing included the split speed bump in combination with other traffic calming devices, and to test this combination on a street narrower than 42'. The most common street width in the City is 36'. SE 17th

Avenue between SE McLoughlin Blvd and SE Tacoma St. was chosen for this test. It is 36 feet wide, with parking allowed on both sides of the street. 85th percentile speeds along this 1 1/2 mile section measured from 37 mph to 39 mph. The speed limit is 25 mph.

A Traffic Committee consisting of area residents interested in solving the traffic problems on SE 17th established speed reduction as one of its primary goals. They circulated a petition for a test, and a majority of residents on SE 17th signed the petition.

The design on the split bumps for this narrower street required some lane adjustments to maintain a minimum 10' lane through the device. Because of the width restriction on SE 17th, parking was removed for 30' opposite each of the split bumps. This incorporated both the 22' length of the bump half, and 7 feet for the approach island. These islands were only 2 feet wide, and set in such a way as to maintain the 10' travel lane. The distances between the bumps ranged from 50' to 85'.



Two issues arose. The parking removal, necessary for the Fire Bureau vehicle moves and lane widths for the buses. While the bus system in Portland, Tri-Met, felt that their buses could operate satisfactorily on the 10' lane, the day following the device installations Tri-Met re-routed the bus line on SE 17th west 1 block to SE Milwaukie (a Neighborhood Collector). Tri-Met contended that the parking removal was insufficient for their needs. 10 to 30 feet of additional parking was removed to allow the buses the additional lane width they required.

Tri-Met had additional concerns about the street designs. Their concern was that if a larger vehicle were to park at the edge of the "no parking" areas, that they might not be able to get through the device. This "tight area" was at the concrete median in advance of the bumps.

Tri-Met concluded that a 10' travel lane is not enough for them to maneuver their buses down the City Streets. They require the option of crossing over the yellow centerline in cases where large vehicles were parked along the street. It was decided that the split speed bumps would be removed, and other methods of traffic slowing would be investigated.

Speed and volume data were collected on SE 17th as well as parallel streets (including SE Milwaukie). The results indicated that the 85th percentile speed had dropped 5 to 6 mph on SE 17 with the speed bumps. In addition, speeds were also reduced on SE Milwaukie, most likely due to the increase in volume.

85th Percentile Changes with Split Speed Bump in Place

Street	Location	85th %ile Before	85th %ile After	Change
Milwaukie	north end	37 mph	36 mph	-1 mph
	south end	34 mph	28 mph	-6 mph
SE 17th	north end	38 mph	32 mph	-6 mph
	south end	37 mph	32 mph	-5 mph
SE 18th	north end	20 mph	21 mph	1 mph

	south end	26 mph	27 mph	1 mph
SE 19th	north end	27 mph	25 mph	-2 mph
	south end	28 mph	27 mph	-1 mph
SE 20th	north end	22 mph	25 mph	3 mph
	south end	24 mph	24 mph	0
SE 21st	north end	25 mph	25 mph	0
	south end	25 mph	27 mph	2 mph
SE 22nd	north end	28 mph	27 mph	-1 mph
	south end	32 mph	31 mph	-1 mph

Table 2

No violations of the devices were observed. Drivers either slowed, or chose another route for their trips.

A comparison between the total area volumes before and after the split speed bumps were installed revealed an overall net loss of traffic volume at both the north end of the area and a greater volume reduction at the south end of the area. They also reduced the amount of large truck traffic that had used SE 17th as a cut-through to avoid the business areas of NE Milwaukie St.

Volume Change with Split Speed Bumps in Place

x-str	Milwaukie	SE 17th	SE 18th	SE 19th	SE 20th	SE 21st	SE 22nd	Total
Ellis	1184	-2094	0	18	52	26	62	-752
Rex	1568	-3136	18	-26	-36	-101	-55	-1768

Table 3 all numbers are in vehicles per day (vpd)

Since the split bumps have been removed, residents of SE 17th report that the speeds have increased and large trucks are again using their streets.

Conclusions and Recommendations

The split speed bump was found to effectively slow traffic speeds without delay to emergency vehicles. In both of the tests, speeds were reduced and Fire Bureau quick response time was maintained. The larger distances between each of the bump halves does not seem to influence driver behavior. Especially on high volume streets, drivers showed no tendency to cross over the center line to avoid the bump.

The test on SE 17th showed that the additional parking removal needed for bus operation conflicted with the neighborhoods need for on-street parking. Tri-met tells us that if more parking could have been removed for the buses, transit buses would have had no difficulty negotiating them on this 36' wide street.

Since parking removal is necessary for these devices to operate well on the street widths tested, they should not be considered for streets where on street parking is important. The advantages of slower vehicle speeds needs to be weighed against the residents needs for on street parking with the final decision to be made by the residents.

*Kathy Mulder, PE, is a senior engineering associate with the City of Portland; OR, Bureau of Transportation System Management, Traffic Calming Program and an Associate Member of ITE.

End Notes:

1. Speed Bump Evaluation Status Report, City of Portland, OR, Bureau of Traffic Management; June 1992.

2. Transportation Element of the Comprehensive Plan, City of Portland, OR Department of Transportation; June 1996.

Offset Speed Tables for Reduced Emergency Response Delay

ITE Technical Conference, March 2004, Irvine, California
Scott Batson, PE

ABSTRACT

With the advent of speed humps (a.k.a. modern speed bumps) to reduce vehicle speeding on residential streets has come the unwanted cost of delay for Emergency Service Providers. Fire equipment, due to its size and weight, is particularly affected by speed humps. Past studies in Portland found delays per hump of up to 9.4 seconds for the 14-foot designs and 9.2 seconds for 22-foot speed tables. Testing of the offset speed table with median islands made advances in reducing delay for emergency vehicles into the 2-second range but was limited to use on wider streets due to the turning needs of larger fire equipment. This report provides a summary of the testing of the offset speed table with median islands as well as a recent alternative and makes a comparison to speed cushions, a tool often used where emergency response delay is of concern. This investigation was undertaken to evaluate a design that would permit the use of the offset speed hump on designated Emergency Response Routes regardless of the street width.

PORTLAND AND SPEED HUMPS

A Brief History

In 1991 the City of Portland's Office of Transportation (PDOT) undertook a study of speed humps in response to public demand for relief from the excessive and continual increase of traffic speeds. As the result of two years of testing, speed humps and speed tables became standard tools for addressing the problem of speeding on Portland's residential streets. In Phase III of the original 1992 speed hump tests, the Fire Bureau indicated a maximum comfortable speed of 20 mph for the 14-foot speed hump and 25 mph for the 22-foot speed table.¹

The 14-foot speed hump was adopted for Local Service² streets that serve as neither a transit street nor a primary fire response route. The 22-foot speed hump, or table, was designed for Neighborhood Collector³ streets that serve higher volumes of traffic, to minimize diversion potential, and on streets that are designated transit or primary fire response routes. Speed tables have reduced effect on transit buses and are easier for fire and emergency vehicles to negotiate than the 14-foot speed hump. The 22-foot speed table has proved effective in slowing average 85th percentile speeds along a street to 30 mph. Seventy percent of residents on traffic calmed streets have perceived a change in speed and over 60% perceived a change in traffic volume.⁴ The Traffic Calming Program has been installing speed humps since 1992, and to date has installed over 650 speed humps and 180 speed tables. Demand for traffic calming in Portland continues with the current street project backlog exceeding 300 projects. It can be stated with certainty that speed humps will for the foreseeable future be a common tool to slow speeding traffic in Portland.

EMERGENCY RESPONSE ISSUES

Benefits have Costs

With the continued success of speed humps the demand for their use increased greatly. And though the Portland Fire Bureau recognized the community's need for reduced speeding, there began to be significant concern that unbridled installation would soon create a cumulative slowing effect that might compromise emergency response time goals.⁵ Friction developed

between PDOT and the Portland Fire Bureau over the competing interests of speed reduction and emergency response time. PDOT's offers to mitigate expected slowing on calmed routes with signal pre-emption on higher classified streets assisted some projects but at a relatively high cost for no clearly defined benefit. The two bureaus agreed that there was a lack of knowledge on how much speed tables delayed emergency response equipment. In 1995, PDOT and the Portland Fire Bureau undertook a joint project to evaluate the slowing effects of speed humps and speed tables, as well as traffic circles. Five types of emergency equipment including an ambulance and heavy rescue vehicle up to engines and trucks and a rear-tiller truck were tested.

Delay Results

As expected, smaller and lighter vehicles were generally less affected by speed humps than larger and heavier vehicles. Also as expected, shorter speed humps tended to cause greater delay than longer speed tables. PDOT's testing took into account that delay caused by a particular device is a function of both the vehicle responding and the desired operational speed of that vehicle and so calculated a range of delay for each device. The delay calculated for 22-foot speed tables (10-foot tabletop) ranged from zero seconds to 9.2 seconds.⁶

Table 1. Speed Table Effect on Fire Vehicles⁶

Vehicle	Weight (lb)	Horse-power	Wheelbase	0-40 mph Accel. Time	Lowest Speed, (mph)	Min Delay 25-mph Response	Max Delay 40-mph Response
Rescue 41	na	185	11' 6"	12 sec.	34	0 sec.	1.5 sec.
Squad 1	23,170	275	14' 6"	17 sec.	24	0.4 sec.	3.4 sec.
Engine 18	34,860	185	15' 5"	19 sec.	21	0.8 sec.	5.0 sec.
Truck 1	53,000	450	21' 0"	20 sec.	22	0.6 sec.	4.9 sec.
Truck 4	53,960	450	13' 0"	22 sec.	16	1.8 sec.	7.7 sec.
Truck 41	42,100	350	37' 6"	27 sec.	14	3.0 sec.	9.2 sec.

This new information was well received by both sides. The engineers at PDOT now had hard numbers to work with instead of perceptions. Furthermore, the Portland Fire Bureau could now argue specifically how much speed humps and tables deteriorated their emergency response goals.

In the spring of 1996 a moratorium was placed on the construction of speed tables on all collector level streets and any local street that had previously been designated a fire route by administrative rule. At that time approximately fifteen pending or active projects were placed on hold. City Council then directed PDOT and the Portland Fire Bureau to work through a public process to create policy that would solve the impasse.

POLICY BASED SOLUTIONS

Rules to Live By

One method to address the concerns raised by the Fire Bureau is with a policy-based solution. In February of 1998, PDOT and the Fire Bureau completed development of a new

classification of street for addition to the Transportation Element of Portland's Comprehensive Plan (now the Transportation System Plan – TSP). Primary Emergency Response Routes are designated streets that:

“Provide a network of emergency response streets that facilitates prompt emergency response. The emergency response classification system shall be used to determine whether traffic slowing devices can be employed, to guide the routing of emergency response vehicles, and to help site future fire stations.”⁷

The intent was to identify a grid of streets on which the majority of all emergency calls are accomplished and ensure that increased delay to emergency vehicles on such routes is avoided regardless of the source of the delay.

ENGINEERED SOLUTIONS

Speed Cushions

The policy-based approach addressed current projects and future projects, but left existing streets that already had speed tables and that became Primary Emergency Response (ER) routes alone. For these streets the Portland Fire Bureau agreed to continue with the status quo, and work with PDOT to determine an engineered solution. PDOT recognized the need to address the Fire Bureau's concerns on ER routes, but also had concerns that residents on newly designated ER routes would still need relief from speeding vehicles.

At the time PDOT was aware of the use in Europe of speed cushions to slow auto traffic. Speed cushions, typically made of rubber, were built just wide enough to affect autos, but not too wide so that freight vehicles, larger fire equipment and transit vehicles could straddle all or most of the device. Tests conducted in the UK found that emergency fire equipment could traverse 3-inch speed cushions 10 mph to 20 mph faster than standard speed humps used there. The same report found that cushion width and spacing affected typical driver speeds and that speeds at the devices varied from 15 mph to 26 mph.⁸ Mobile Alabama has also found speed cushions to be effective at achieving 85th percentile speeds in the 24 mph to 26 mph range for the typical driver.⁹ The City of Austin reported negligible delay to fire equipment as compared to typical speed humps there.¹⁰

The Portland Fire Bureau considered speed cushions a likely solution to delay issues associated with speed tables and often advocated for their testing. PDOT had considered speed cushions, but significant concerns remained that reducing delay for emergency equipment also meant reduced slowing for typical traffic. Speed cushion use was more common in Europe where fuel prices tend to be significantly higher than fuel prices in the U.S. This price difference was perceived to cause private vehicles in Europe to be more fuel efficient and thus smaller, with narrower wheel tracks, than typical passenger vehicles in the U.S. Narrower passenger vehicles in Europe would mean it is easier to find a speed cushion width that a fire truck or transit vehicle could straddle but that private vehicles could not. The similarity in width of the wheel track of vehicles in the United States was the driving force behind PDOT's reluctance to test speed cushions (Table 2, next page).

Table 2. Typical Vehicle Track Width

Vehicle	Average Track Width*
Private Vehicle – Low ¹¹	4 ft. 2 in.
Private Vehicle – Average ¹¹	4 ft. 11 in.
Private Vehicle – High ¹¹	5 ft. 9 in.
Typical Portland Fire Engine	6 ft. 5 in.
Typical Portland Aerial Ladder Truck	6 ft. 7 in.
Typical Portland Rear-Tiller Truck	6 ft. 8 in.
Typical Tri-Met Transit Bus	6 ft. 3 in.

*Center to Center

Compounding the issue of track width was the common use of dual rear wheels for heavier vehicles like transit buses and fire trucks. Dual rear wheels in heavy vehicles mean the clear space between the wheels of large vehicles more closely matches the track width of sedans and sport-utility vehicles common in the U.S. Finding a speed cushion wide enough to slow most private vehicles and yet narrow enough to permit fire trucks and transit vehicles to pass easily, without overloading those heavier vehicles' rear axles proved difficult. Also, the use of speed cushions means there are intentional gaps, or channels, between devices in a multi-device installation (see Photo 1).

Photo 1. Speed Cushion, Lafayette, LA.

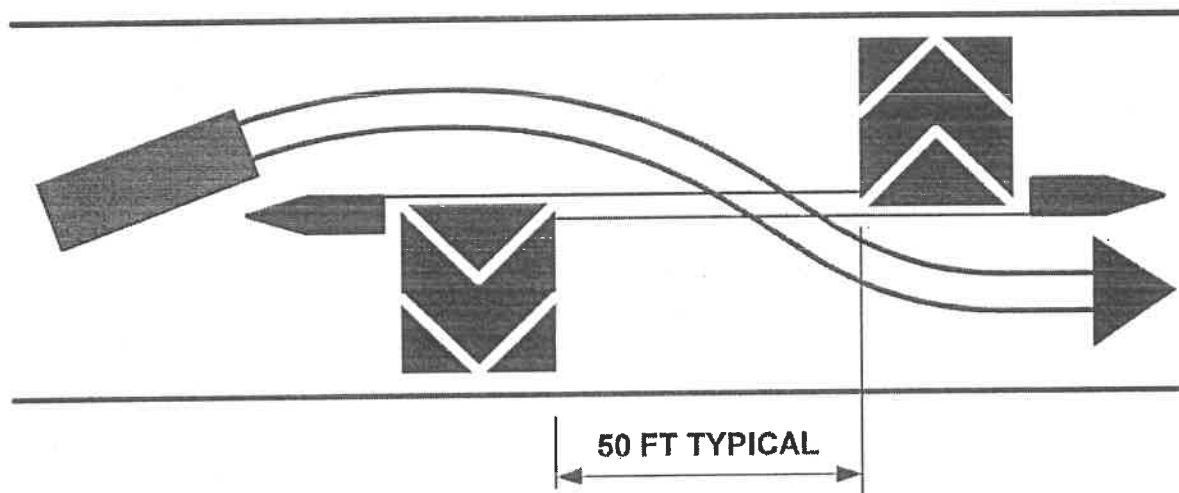


The UK study also found that 45% of drivers aimed for the gaps when traversing speed cushions and noted concern when gaps coincided with street centerlines.¹² Finally, the use of speed cushions and the need for larger vehicles to straddle the devices meant that conflicts with parked vehicles were possible, eliminating the original benefit to using speed cushions.¹³

Offset Speed Table with Median Islands

In 1997 PDOT began testing an alternative to the speed cushion concept. PDOT'S design used a standard speed table that was constructed across only half of a street. The second half of the speed table was constructed downstream of the first and in the opposing lane. As emergency equipment is able to use any portion of the roadway to accomplish a response, the space between the speed table halves permitted emergency vehicles to cross the street centerline and slalom around them in a serpentine pathway (Figure 1). Constructed with the offset speed tables were median islands on the outside approaches to deter civilian drivers from crossing the centerline. In addition, a double yellow centerline was added approaching each island and quadruple yellow centerline with raised pavement markings were added between the speed table halves. The dense pavement markings between the speed table halves gave an illusion that a median continued the entire distance. The addition of the islands and striping was done to deter drivers from mimicking the pathway emergency vehicles could take.

Figure 1. Offset Speed Table with Islands and Emergency Response Path.



Tests of the offset speed table with islands were conducted on two public streets, SE Market and SE 17th, in 1998. The testing of the offset speed hump with islands successfully demonstrated fire truck access speeds of 20-30 miles per hour through the pair of speed tables. Response delay was reduced from a maximum of 9.4 seconds for standard speed tables⁶ into the 2-second range.¹⁴ Video of the test site on SE Market showed no indication of confusion on the part of the drivers, nor any violations of drivers trying to avoid the device at any time.¹⁴ The testing also revealed that the offset speed table with median islands has limited application. Street width must be at least 40 feet, curb to curb, to provide for the serpentine path of Emergency Equipment and parking removal is often necessary opposite of each speed table half (see Figure 1). Additionally, where the street is less than 40 feet, transit drivers and other wide vehicle operators

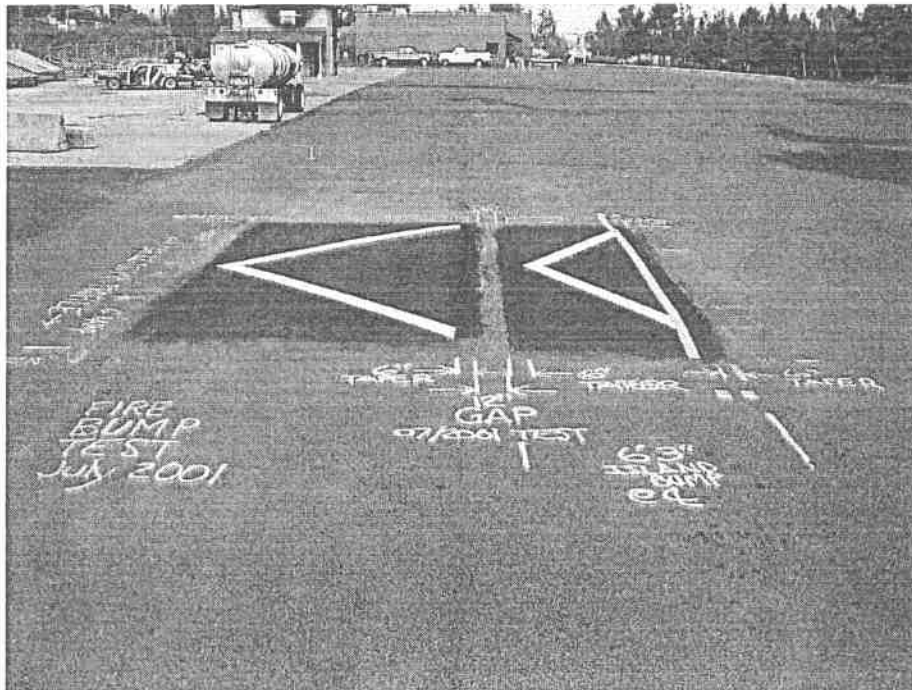
may feel uncomfortable traveling between the island and parked cars. Where a 12-foot travel lane between the island and parked cars is not possible, additional removal of parked vehicles adjacent to the island on the speed table side might also be necessary. Many of Portland's Neighborhood Collector streets are less than 40 feet and coincide with Primary Emergency Response Routes. Also, for traffic calming to be considered on Neighborhood Collector streets in Portland, they must have a minimum of 75% residential zoning. Under such conditions, on-street parking demand is generally high, making parking removal politically difficult.

Offset Speed Tables without Median Islands

In 2001 PDOT and the Portland Fire Bureau initiated another round of testing to determine if a speed cushion like device could effectively slow traffic while reducing response delay for emergency vehicles. The concept was to use the standard offset speed hump layout without the islands and adding a speed cushion like channel. In the test a channel was placed through a standard half-street speed table, aligned near the center of the travel lane. The object was to permit a fire truck to place the left side just over the centerline while aligning the right-side wheels with the channel. The hope was that providing the channel would effectively nullify the speed table's effects on large fire equipment.

PDOT constructed a prototype device at the Fire Bureau's training facility (Photo 2). This is a controlled area not subject to general traffic and permitted a variety of vehicles to test the device while data was collected. The primary purpose of this test was to determine what benefit the channeled speed table design provided for emergency vehicle response time. This testing also assisted in answering concerns of PDOT over driver control questions as well as refining the design and evaluating constructability issues.

Photo 2. Offset Speed Hump with Channel Test Object – Looking Upstream.



The test device was constructed at Station 2 the week of July 16, 2001. The test object was a standard 22-foot speed table with 6-foot parabolic approach ramps and a 10-foot flat section with a maximum height of 3 inches. A channel was constructed offset from the centerline resulting in a 6-foot 3-inch wide cushion-like object that emergency equipment could straddle. The edge tapers for the channel and centerline edge were constructed with a 1:2 slope. Formal testing, using eight vehicles, was conducted on July 23, 2001. Each vehicle was driven over the device twice with drivers directed to aim for the channel. For the first run drivers were directed to attain 25 mph before crossing the speed table. For the second run the target speed was 30 mph. In past tests the typical speeds of fire trucks and engines crossing a standard 22-foot speed table varied from 14 mph to 21 mph.⁶ The majority of delay at the standard 22-foot speed table is due to the larger fire vehicle's slow acceleration. Attaining typical crossing speeds above 25 mph with the new design would represent a significant reduction in delay for emergency response and was the chosen target speed for a successful test. Each vehicle successfully traversed the test device near or above 25 mph as shown in Table 3.

Table 3. Emergency Vehicle Speed over Offset Speed Table with Channel

Vehicle	Weight	Maximum Speed At Speed Table (mph)	
		First Run 25-mph Goal	Second Run 30-mph Goal
2000 Ford Crown Victoria Police Interceptor	3900 lb.	24	30
2000 Chevrolet Police Camaro	3500 lb.	25	30
2000 Kawasaki KZ 1000 Motorcycle	600 lb.	>26	30
1998 Ford Van – Police Photo Radar Unit	4,700	>25	>30
Fire Rescue 2 - 1994 Ford Fire Rescue	10,500	>25	>30
Engine 2 - 1995 H&W Fire Engine	38,150	25	30
Fire Truck 2	na	30	35
Truck 13 - 1994 Simon LTI, Rear Tiller Fire Truck	58,000	>25	30

* The police vehicles did not attempt to use the channel

Drivers that participated in the testing expressed very favorable comments regarding the channel design and the significant reduction in discomfort for personnel, though concern remained about citizens that might stop on a speed table when an emergency vehicle approaches. The Portland Bureau of Maintenance, who constructs nearly all speed tables in Portland, noted the narrower section between the channel and centerline was labor-intensive to construct and may double the cost of construction over a typical speed table placed with the aid of machines.

The testing also confirmed that the original device proposal might be ineffective for speed reduction. As previously stated, placement of the channel so that the majority of drivers straddle the channel is critical to achieving the desired slowing effect for typical traffic. As originally proposed, and due to current vehicle dimensions, PDOT was unable to identify a channel location that ensured the success of the proposed device for slowing traffic. By placing one set of wheels in the channel a sedan size vehicle driven over the speed table attained a speed of 30 mph without significant discomfort to the driver.

However, the determination that a channel greatly reduced the effectiveness of the speed table for typical traffic even though only one set of wheels could be placed in the channel led to a revised design. In the revised design a half-street speed table without a median or channel would be evaluated. The new proposal would require emergency equipment to cross the standard speed table profile with the right side of the vehicle, but the left side of the vehicle could cross just over the centerline and avoid the speed table profile completely. With the channel removed, vehicles operated by the general public would encounter a standard 22-foot speed table profile, ensuring continued speed reduction. Another advantage to a full half-street speed table is that it can be built faster, and at lower cost, since more of the device could be constructed with mechanical equipment.

A second series of field tests using only the four Fire Bureau vehicles were conducted on July 26, 2001. The second round of testing included target speeds of 20 mph, 25 mph and a free run where the driver picked the speed. The Fire Bureau vehicles ran the same course again, and radar recorded their top speeds while traversing the speed table as follows:

Table 4. Emergency Vehicle Speed With Only Right Half on the Speed Table.

Vehicle	Maximum Speed At Speed Table (mph)		
	First Run 20-mph Goal	Second Run 25-mph Goal	Third Run Driver Choice
Fire Rescue 2	>20	<25	>30
Fire Truck 2	>20	>25	>30
Fire Engine 2	>20	>25	>30
Fire Truck 13, Rear Tiller	>20	>25	>30

As can be seen, the modified design continued to provide excellent travel speed as compared to typical speed table speeds of 14-21 mph for Fire Bureau Equipment.⁶ Drivers that participated in the testing continued to express positive comments about their comfort using the speed table as modified.

NEXT STEPS

Early Live Testing

The nearby City of Beaverton installed offset speed tables without islands on SW 87th-Birchwood-Laurelwood in the summer of 2003 (Photo 3, next page). Offset speed tables were chosen due to the designation of the street for emergency response. Before construction of the speed tables the 85th percentile speed was measured at 34 mph in a 30-mph zone with 25% of

drivers exceeding the posted speed. After construction the 85th percentile speed reduced to 30 mph with 15% of drivers exceeding the posted speed. Vehicle volume on the street reduced from an average of 5800 vehicles per day (vpd) to 5400 vpd. The offset speed tables were originally constructed with only pavement striping to communicate to drivers to remain on their side of the street due to the weather. Subsequent to construction Beaverton received complaints from local residents about driver circumnavigation of the offset speed tables by crossing the centerline. The City of Beaverton added raised pavement markers with inset reflectors to deter such behavior (see Photo 4) after the weather warmed up in 2004. The City of Beaverton reports that complaints regarding centerline violations are no longer common from local residents.

Photo 3. Beaverton Offset Speed Hump – SW 87th Avenue.

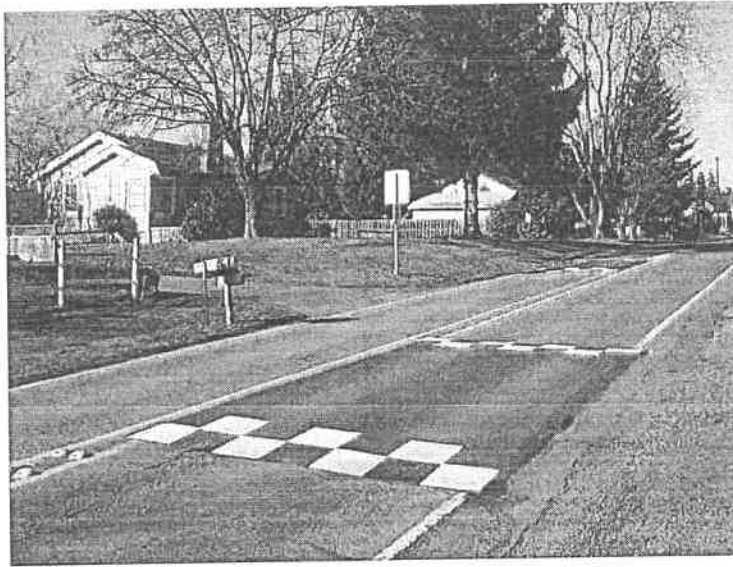
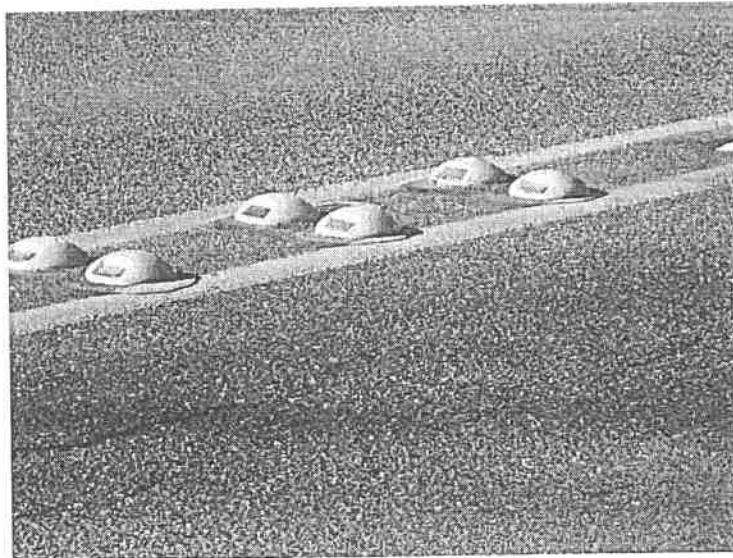


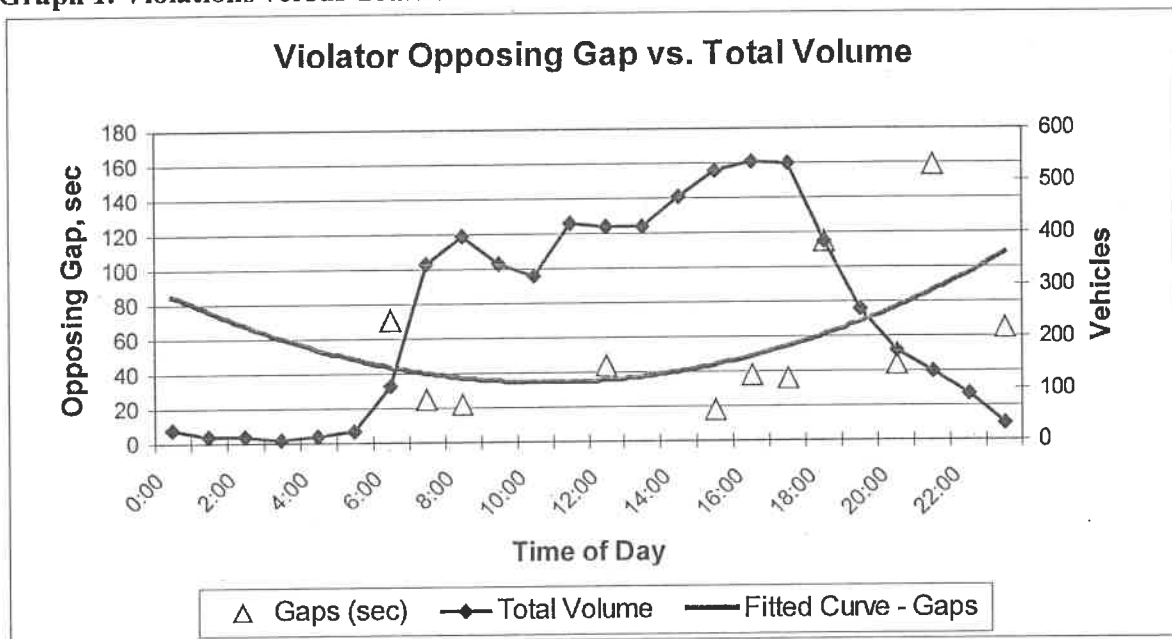
Photo 4. Beaverton Offset Speed Hump Centerline RRPMS.



PDOT Testing

It is expected that the offset speed table will be self-regulating in regards to centerline violations and such self-regulation is sensitive to opposing traffic volume. As opposing volumes increase fewer drivers likely to violate a double yellow centerline will do so (see graph 1). PDOT collected video at the Beaverton site to determine the frequency of centerline violations. Approximately 13 vehicles in a 24-hour period violated the centerline to some extent, either completely or partially avoiding the offset speed tables. This represents a violation of 0.22% of the total population of drivers. The average length of time a driver was within a portion of the opposing lane (exposure) during such maneuvers was 2.88 seconds with a standard deviation of 1.13 seconds. The opposing headway gap, the length of time before the next opposing vehicle passed the offset speed table after a violation occurred, averaged 22 seconds with a standard deviation of 10.43 seconds. The exposure and opposing headway analyses are conservative in that data corresponding to opposing gaps in excess of 60 seconds (5 of the 13) were discarded.

Graph 1. Violations versus Traffic Volume



FUTURE RESEARCH

With a speed table that is only constructed to the centerline of a street comes the possibility that civilian drivers will mimic the pathway intended only for emergency service personnel. Opposing vehicle traffic plays a part in making sure drivers stay on their side of the road and slow down. Unknown at this time is what threshold of traffic volume is the minimum needed to ensure that drivers will remain on their side of the street. PDOT is currently seeking a suitable City street to advance testing the offset speed table concept.

SUMMARY

From the outset PDOT has had concerns that efforts to nullify the effect of speed humps for emergency response, as with speed cushions, would also render them ineffectual at reducing speeding. Testing conducted by PDOT and the Portland Fire Bureau successfully showed the ability of the offset speed table design to reduce emergency vehicle delay, especially the largest trucks that normally suffer the greatest delay. A reduction in maximum delay from 4.8 seconds at standard speed tables where the target response speed is 30 mph to the typical 2 second delay at offset speed tables represents a better than 50% reduction in emergency vehicle delay. PDOT is confident that the offset speed table will continue to reduce speeding as effectively as standard speed tables. PDOT was also successful in identifying minor adjustments to the final design to improve constructability. The design changes discussed in this paper, and the cooperation between PDOT and the Portland Fire Bureau to explore a compromise that avoids an all or nothing choice has gone a long way to solving the issue of emergency response delay caused by speed tables.

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A Brief History of the Traffic Calming Program in Portland

- A citizen survey reveals excessive traffic speeds and volumes as threats to feeling comfortable and safe as a non-motorized user of residential streets (early 80's).
- Origins of Comprehensive Plan Policies that directed improvements to Local Service and Neighborhood Collector Streets to reduce the negative impacts of excess traffic on residential livability and safety.
- The adopted update of the ASCP contained the directive to create a "Neighborhood Traffic Program."
- Established the Neighborhood Traffic Management Program (NTMP) through Council Resolution No. 33706 on July 12, 1984, with one of the nation's first systematic approaches to the mitigation of residential traffic problems.
- Citizen Advisory Committee (CAC) appointed to undertake Neighborhood Traffic Management Plan (NTMP) evaluation and examine how well the NTMP objectives were being met.
- Technical Advisory Committee (TAC) also appointed to examine the effectiveness of traffic circles, impacts of traffic management devices on emergency vehicles, new devices and other issues of a technical nature.
- Initial tests on 12' speed bump design conducted in Willamette Park. Fire Bureau and other agencies participate in the test.
- Citizen concern regarding excessive traffic speeds and volumes on residential streets is reaffirmed in a 1992 Bureau of Transportation Management (BTM) survey of licensed drivers.
- Transportation Element (formerly ASCP) adopted by City Council in October 1992 included major policy change to expand the use of residential traffic management techniques to Neighborhood Collector Streets.
- Speed Bump Evaluation report published in June 1992 containing results of field studies on three bump designs: 12', 14', and 22'. Fire Bureau participated in field studies.
- Results of CAC and TAC evaluation of NTMP adopted by City Council Resolution No. 35001, June 10, 1992.
- Significant changes resulted from the two reports: implementation of an Impact Threshold Curve for traffic diversion, modification of the ballot area,

improvements to the visibility around traffic circles and the authority to use of speed bumps as traffic management devices.

- Peer Review Report on Portland's Traffic Circle Program found that reported accident rate had decreased by 28 to 84% at intersections where circles had been installed.
- CAC and TAC committees established to develop the Arterial Traffic Calming Program, the first program of its kind in the United States to address traffic management problems on Neighborhood Collector Streets with at least 75% residential zoning.
- City Council adopts Arterial Traffic Calming Program (ATCP) in September 1993 (Resolution #35183; September 22, 1993) Representative from Fire Bureau testified in support of this new program and indicated that the agency was satisfied that their concern about "cumulative impact" had been adequately addressed.
- Proposed changes to both the NTMP and ATCP were presented to and adopted by Council Resolution No. 35317, October, 19, 1994. ATCP and NTMP were consolidated and renamed the Traffic Calming Program (TCP); project planning process reduced; Streamlined Speed Bump Projects were proposed to address speeding problems on Local Service Streets with low traffic volumes and high speeds to reduce the backlog of requests; Residential Speed Bumps Purchase Projects were proposed to enable residents on some Local Service Streets to pay for speed bumps.
- 1995/1996: BTM and Fire Bureau conducted field studies of five representative fire response vehicles with traffic circles and speed bumps, determining typical slowing caused by each device.
- 1996: As a compromise with the Fire Bureau, Streamlined Speed Bumps and Residential Purchase projects were restricted to Local Services Streets that do not appear on the Fire Response Routes map, cutting the pool of eligible almost in half, until an official Major Emergency Response route classification and map is added to the TSP (Completed in 1998).
- Review of eight TCP projects found reported accidents reduced by 45% at intersections treated with traffic circles. Review of 17 projects involving both traffic circles and speed bumps indicated that the overall accident frequency was reduced by 32% for the length of the street treated. On streets where speed bumps have been installed, an overall average speed reduction of 8 mph has been produced.
- In 1997 PBOT and Portland Fire and Rescue (PFR) began testing 'fire friendly' offset speed tables (with approach islands) to determine the

parameters for construction and to reduce delay for the largest of the fire vehicles. While tests were conducted on City streets, and the estimated delay was reduced from 10 seconds per speed table to 2 seconds per offset speed table, no officially approved device was adopted.

- 1999: Low volume Neighborhood Collector streets were approved to purchase simple speed bump projects under the Residential Speed Bump Purchase Program by City Council.
- Portland Safe Routes to School (SR2S) began to develop programming in 2000, when the national conversation began with the funding of the Marin County program and the Oregon Walk + Bike to School committee was formed. The City of Portland took a step toward formalization when the State of Oregon passed House Bill 3712 (known as the 'Safe Routes to School Bill') in 2001. To date, over eighty elementary schools have been served and over forty have ongoing education programs.
- In 2001, PBOT and PFR again tested speed cushions and the offset speed table design, this time without the leading island. With an island, fire vehicles were required to drive in the opposing lane to go around the devices. Without the islands, fire vehicles only had to straddle the centerline. 22-foot speed cushions did not appear to have any effect on standard vehicle speeds. No device was approved or tested on City streets upon completion of these tests, though devices constructed in Beaverton were evaluated.
- 2003: Community and School Traffic Safety Partnership (CSTSP) created.
- 2004: Subsidized Residential Speed Bump Purchase projects authorized where the City funds 60% of the project costs for low volume Local Service streets with approved petitions, or low-volume Neighborhood Collector streets with approved petitions that also have Neighborhood Association endorsement.
- 2006/2007: City funding for traffic calming is reduced to only those projects that are part of a larger programmatic goal, such as Safe Routes to School, or Neighborhood Greenways (formerly Bike Boulevards), or are funded by private donations.
- 2005: Safe Routes to School (SR2S) Program engineering evaluations begin. Thirty-two schools have had engineering evaluations.
- 2009: Initiation of new bike classification – Neighborhood Greenways (NGs) – that includes traffic calming to achieve 20 mph along the project street and traffic volumes below 1,000 vehicles per day.
- 2010: Adopted MUTCD Option A pavement marking for speed bumps.

- 2012(?): The Community and School Traffic Safety Partnership (CSTSP, formerly Traffic Calming Program) is merged with Transportation Options to become the Active Transportation Division.
- 2011: PBOT and PFR were directed to evaluate and test a 'fire friendly' traffic calming device. PBOT agreed to evaluate 14-foot speed cushions (a speed bump with channels for fire vehicle tires), and after an initial test at the PFR training facility, speed cushions were installed on NW Cornell, between Lovejoy and the first tunnel, replacing the existing speed tables. PBOT also changed the design on SW 51st, Maplewood to Multnomah, from speed bumps to speed cushions at the request of PFR. Tests show that it is likely that speed reductions to near 30 mph are probable, but reductions to near 25 mph will be difficult. Also, the sizing of the cushions has not been finalized.
- 2013: Funding for approved neighborhood greenway projects ceases as of July first. Current approved projects and pending work is placed on hold. Traffic calming for SR2S and Bike Lanes is dependent on Federal funding.